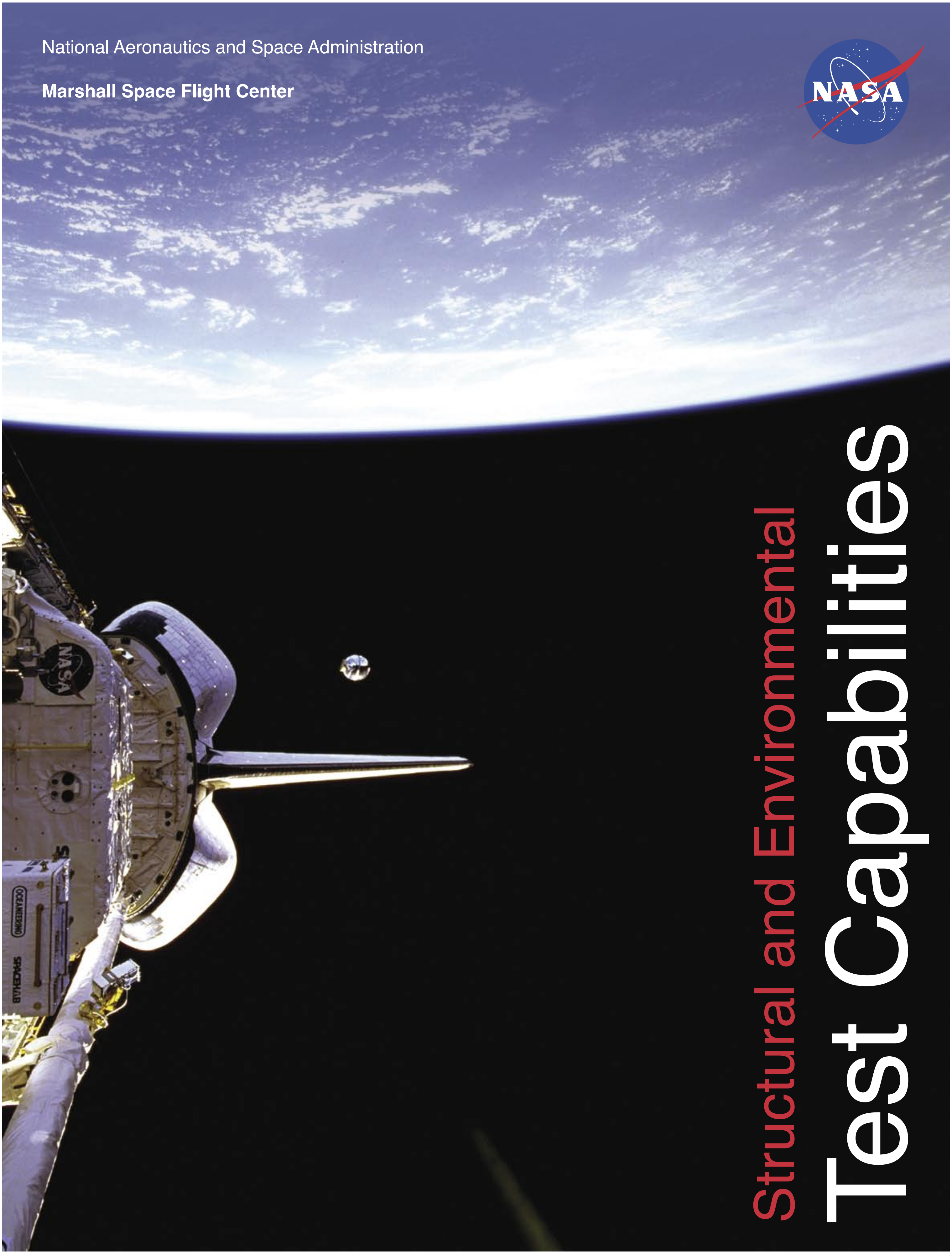
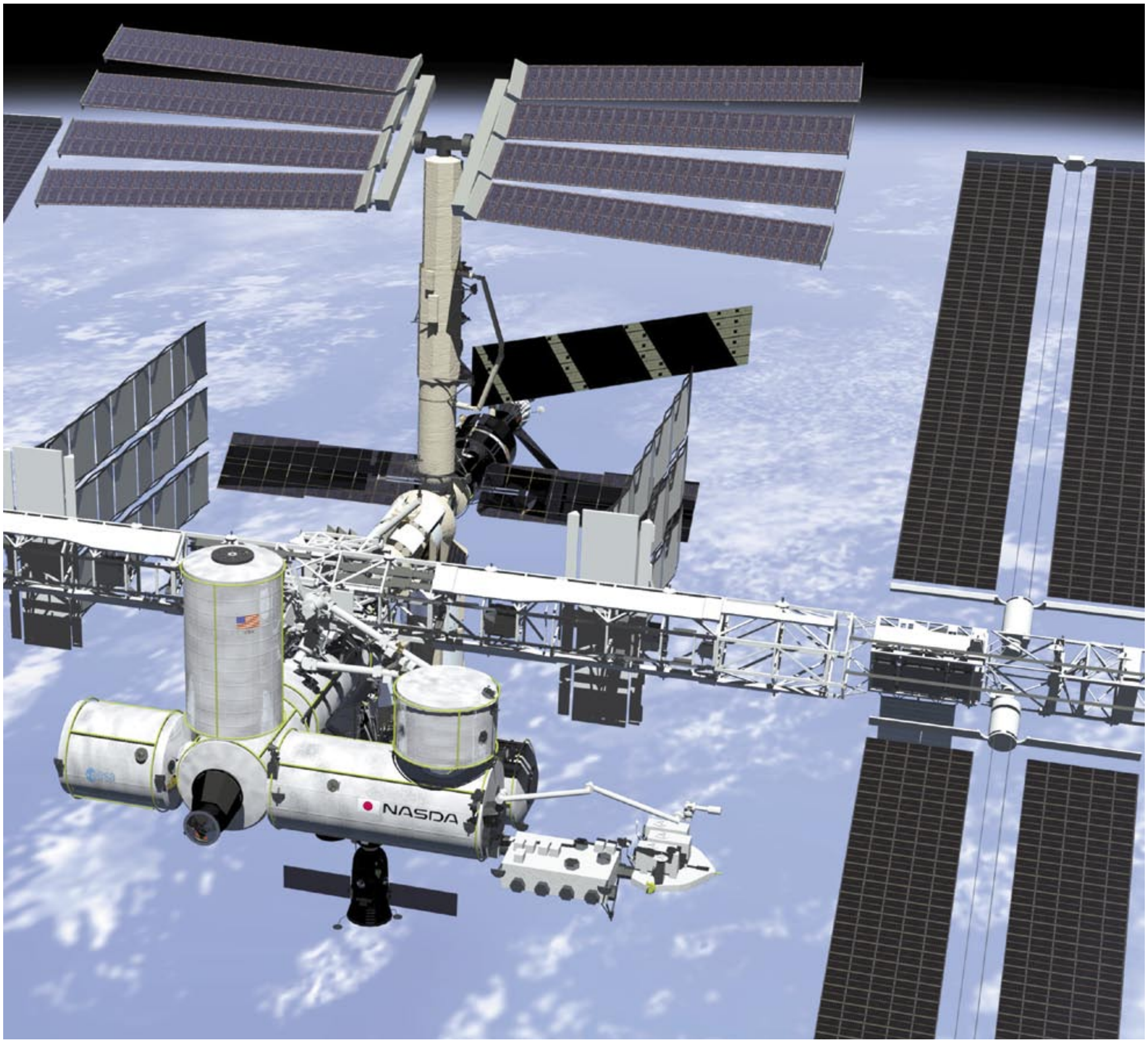
National Aeronautics and Space Administration

Marshall Space Flight Center



Structural and Environmental Test Capabilities



Artist rendering of the *International Space Station*.

Cover Image: STARSHINE released from *Discovery* cargo bay.

Foreword

The Marshall Space Flight Center (MSFC) Structural and Environmental Test Division facilities are an essential element in the development of space flight hardware and support for space research. The Structural and Environmental Test Division provides NASA with ground test capabilities for development, qualification, and acceptance testing of space flight hardware. This facility is chartered to maintain proficiency in advanced test and evaluation technologies and to establish ground test capabilities compatible with requirements of its NASA Mission Directorates and Center of Excellence assignments. Its viability is derived from a technical staff recognized in the aerospace community for research and development accomplishments and a world-class institutional base that includes laboratory facilities and infrastructure. The Structural and Environmental Test Division's experience base extends from the pre-NASA Explorer program through Saturn, Apollo, *Skylab*, Space Shuttle, and the Hubble Space Telescope, on to the current *International Space Station* (*ISS*) and Shuttle Return To Flight eras. While testing NASA's space hardware is the primary mission of the Structural and Environmental Test Division, the facilities also support programs for other institutions including the Department of Energy, the Environmental Protection Agency, the Department of Defense, and many colleges and universities. The Structural and Environmental Test capabilities include the design of special test equipment, static and cryogenic structural strength, vibration, acoustic, pyrotechnic shock, modal survey, thermal vacuum, launch simulation, thermal humidity, and thermal altitude testing.

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Introduction

The Structural and Environmental Test Division is staffed and equipped for specialized testing of aerospace structures and systems and has a broad base of test capabilities to accommodate test requirements of Government agencies, the private sector, and academic institutions. Structural strength, dynamic load, environmental space simulation, and experimental test activities are planned and conducted in the Structural and Environmental Test Division to support the design, development, certification, and operation of flight structures, payloads, systems, and components.

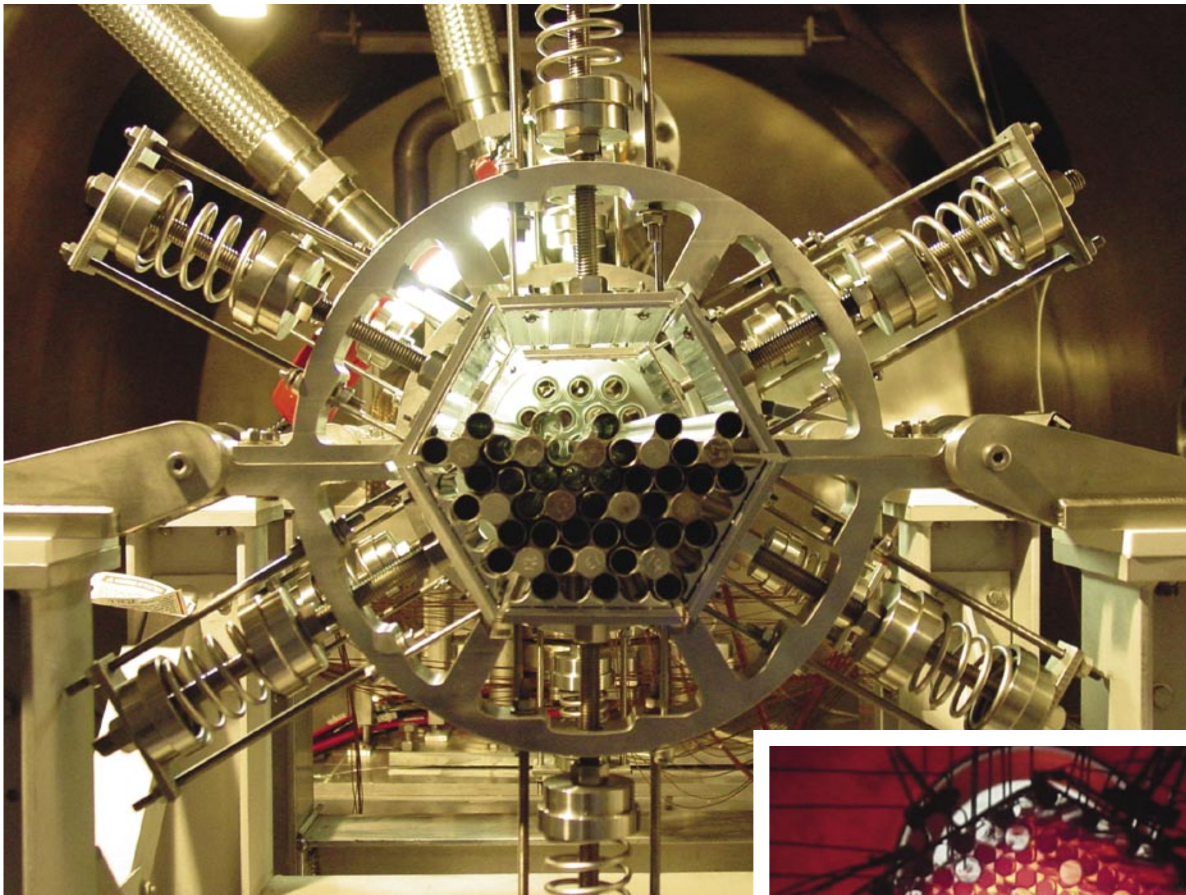
Flight articles are tested to the requirements of launch, ascent, descent, and on-orbit conditions as well as shipping and storage conditions and environments. Experimental testing supports research that leads to innovative flight hardware development and certification. The Structural and Environmental Test Division infrastructure and expertise are available for working with program-critical space flight hardware. The Structural and Environmental Test Division is comprised of four branches: Structural Strength Test, Special Test Equipment Design, Structural Dynamics Test, and Environmental Test.

Structural Strength Test capabilities include full-scale tests using support structures anchored to bedrock, real-time data acquisition and processing, computational networks that support stress analysts' testing, and test-beds with multiple-degree-of-freedom configurations. Test article boundary constraints, input forces, and response parameters are tailored to specific test article characteristics. Test methodologies are developed or expanded as required to accommodate full-scale testing relative to unprecedented design concepts, new materials, and payload mission objectives.

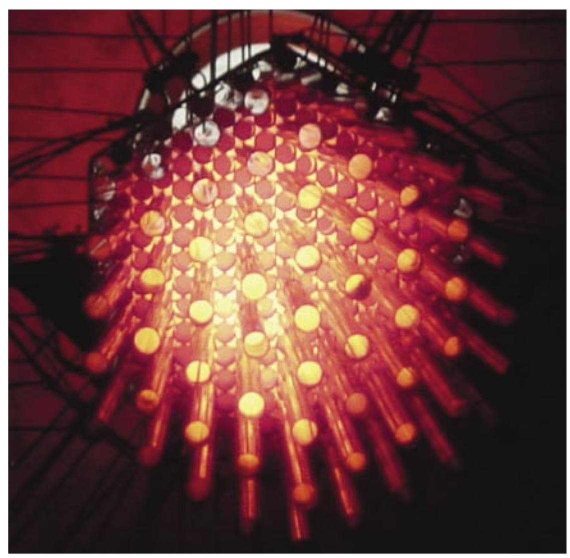
Special Test Equipment Design capabilities include high- and low-pressure cryogenics; liquid nitrogen and water systems; vacuum chambers, piping, and pressure vessels; test stand design; structural load test-beds and lifting hardware; and multiaxis linear motion systems design, mode-specific mounting hardware, and mass simulators.

Structural Dynamics Test technologies are planned, developed, and applied to the requirements of structural analysis, flight criteria, and institutional objectives. Primary emphasis is on flight certification testing to simulated dynamic forcing functions, development tests to determine structural performance characteristics, experimental tests to derive structural dynamic properties, and experimental tests to evaluate dynamic control systems.

Environmental Test capabilities include thermal vacuum, launch pressure simulation, vacuum bakeouts, optical cleanliness bakeouts, thermal humidity, and thermal altitude testing. Vacuum chambers are operated 24 hours a day, 150+ days each year. The close proximity and variety of chambers within the facility provide flexible and efficient testing solutions.



Support fixtures designed for Safe Affordable Fission Engine development program.

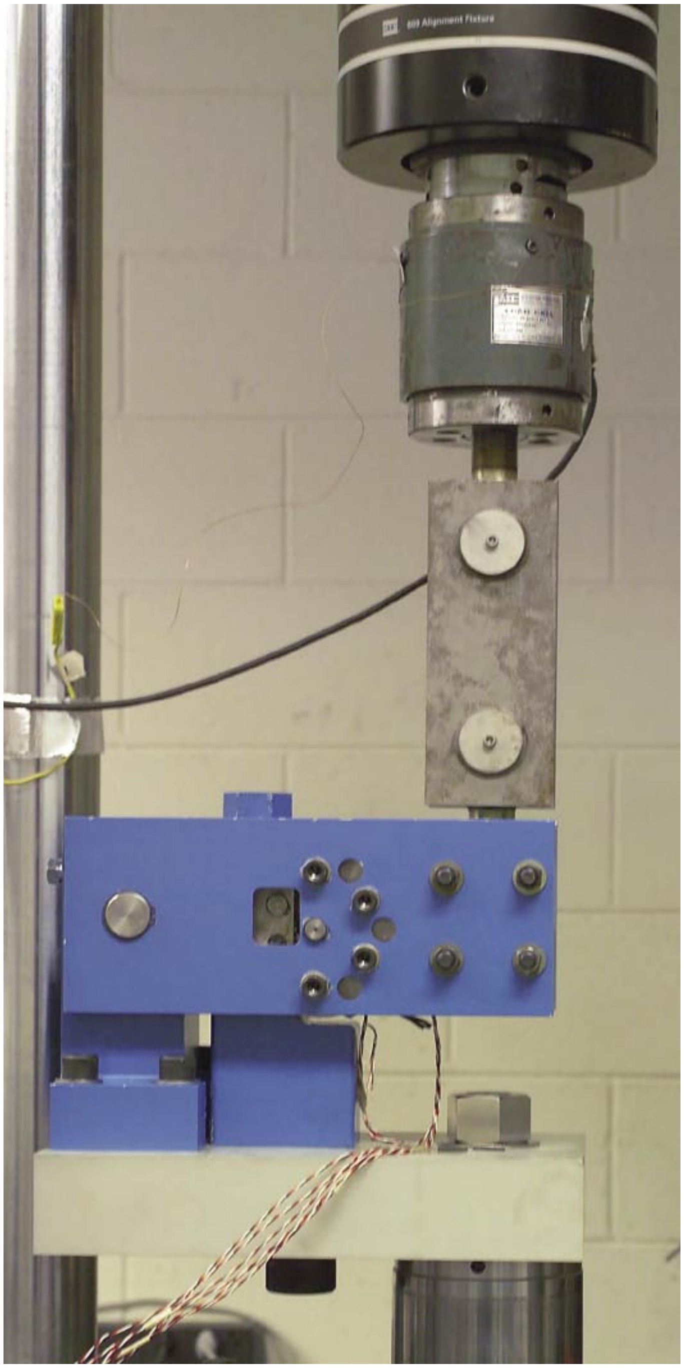


Special Test Equipment Design

The Special Test Equipment Design Branch has been MSFC's leading design organization for ground test hardware since the Center's inception. This hardware, called Special Test Equipment, includes test stands, test-beds, cryogenic and noncryogenic fluid delivery systems, high-pressure and/or high-temperature pressure vessels and chambers, vacuum systems, load reaction and application structures, load line components, linear and rotary motion devices, R&D prototypes, flight hardware mockups and simulators, tooling fixtures, handling and transportation equipment, and personnel access stands. The Branch has also provided design support to the MSFC Public Affairs Office, the U.S. Space & Rocket Center, and MSFC's mockup of the *ISS*.

The Branch is comprised of two teams: Piping Design and Structural Design. The engineering skills mix of each of these two teams reinforces the capabilities of the other team. This relationship provides the ability to accomplish design tasks that neither team could perform alone and results in better products for our customers.

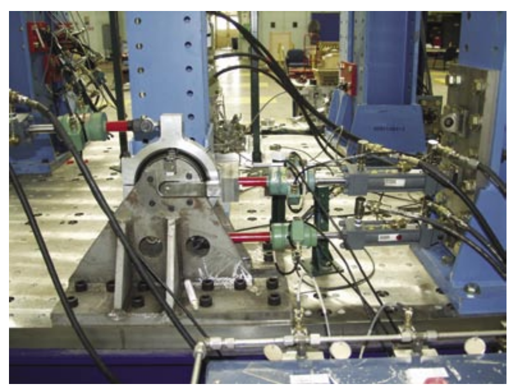
Design of mockups and simulators for flight verification such as this ultralightweight test mockup of a section of the Delta IV rocket.



Columbia accident investigation—Speedbrake Geartooth Proof Test.

The Piping Design Team capabilities include the performance of design analyses and the piping design for cryogenic delivery and vacuum systems. This team's experience includes design of systems for gaseous and liquid oxygen, hydrogen, nitrogen and RP1; high-pressure water, methane, and carbon dioxide. The team's designs have been used for testing advanced concepts such as solar thermal propulsion, solar sails, hot hydrogen, and slush hydrogen.

The Structural Design Team capabilities include design analyses and designing structural, mechanical, and vibration fixtures. The team's experience includes designs for cryogenic structural tank tests, static structural test-beds and reaction structures, small-scale component test hardware, dynamic and vibration test hardware, lifting and transportation equipment, and thrust measurement systems.



Columbia accident investigation—Speedbrake Geartooth Wear Test.

The Special Test Equipment Design Team's project history includes the following types of effort:

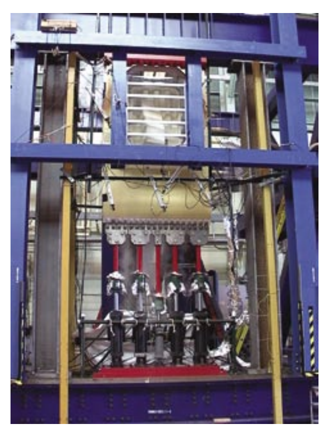
- **Investigation Testing and Return To Flight**
- **Nuclear Propulsion Research**
- **Cryogenic Structural**
- **Advanced Concept Development and Propulsion R&D**
- **Flight Hardware Verification Testing**
- **Tooling**
- **Joint Agreements with Industry**
- **Liquid Fuel Engine Test Firings**
- **Structural and Vibration Component Testing**
- **Static Structural Load Test Beds**
- **Optics Development**
- **Large Scale Structural Testing**
- **Lab Equipment**
- **Vacuum Systems Design**
- **Solid Motor Test Firings**

Pad abort demonstrator at TS116.

Designs for complex load application and reaction hardware, including those used for the structural testing of the X–33 liquid oxygen tank.

Cryogenic structural testing of the External Tank lightweight test article.

External Tank panel bipod test.

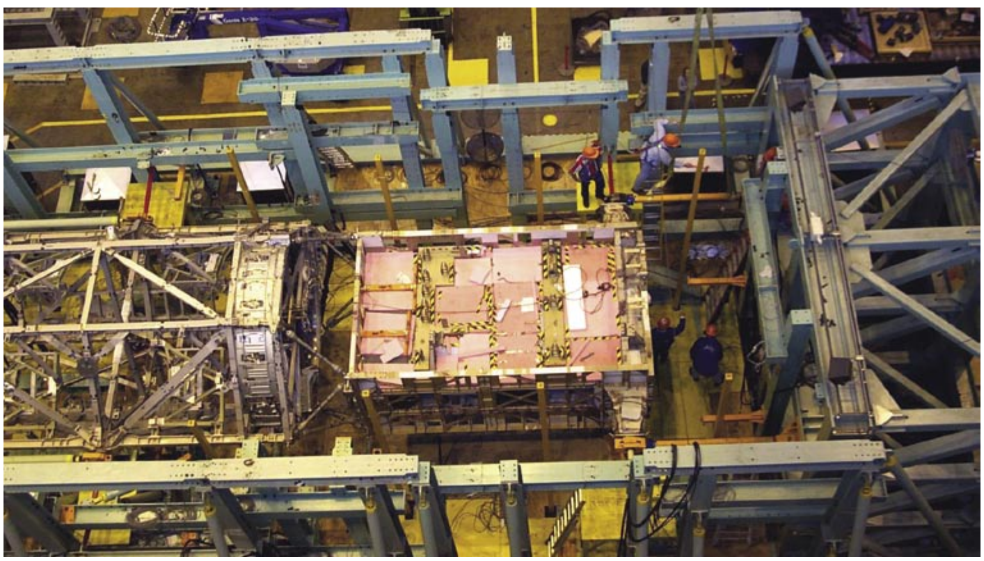


External Tank panel.

Rocket Propellant Composite Tank.

Structural Strength Testing

Structural strength testing is a simulation of a product's actual service life loads on a test article, the measurement and evaluation of the test article's response parameters, and the correlation of test data with analytical models. It involves imposing and controlling discrete loads, temperatures, and pressures to affect the interactive behavior of test articles to simulate actual service life conditions. Forcing functions are derived with hydraulic actuators, heating and/or cooling systems or fluids, and pressurization systems. Response characteristics are measured in terms of strain, temperature, and displacement. Measured data is processed to determine test article reactions to applied loads, to verify design concepts, and to correlate analytical models. Structural test systems can integrate audio, video, still photography, nondestructive evaluation techniques, and user-supplied measurement types into the overall test system.



Quasi-static test of *ISS* Truss Segment.

Large Structure/Full-scale Quasi-static Load Test

These tests are typically conducted in the high-bay areas of the facility. The high bays are designed for full-scale quasi-static structural load testing and functional performance verification. Loading profiles are applied using automatic, closed-loop servo load control systems. Load control capability for quasi-static and fatigue testing modes is in the range of 240 active channels. Loading profiles, application rates, and release of loads are computer controlled with load limit and error tolerance controls utilized for test article protection. An extensive inventory of force transducers and hydraulic actuators are available, ranging from a few pounds to several million pounds capacity. Measurement data is acquired by the Structural Loads Test Measurement Acquisition System (SLTMAS). The SLTMAS is comprised of 4,600 channels of signal conditioning with an overall system accuracy of ± 0.075 percent of full-scale range. The data acquisition sample rate is dependent on the total number of channels. For low numbers of channels, a sample rate of 100 kHz is possible. Sensor data are processed and can be viewed in real-time on multiple stress analyst stations, where test data is displayed in tables or plots specified by the analyst.

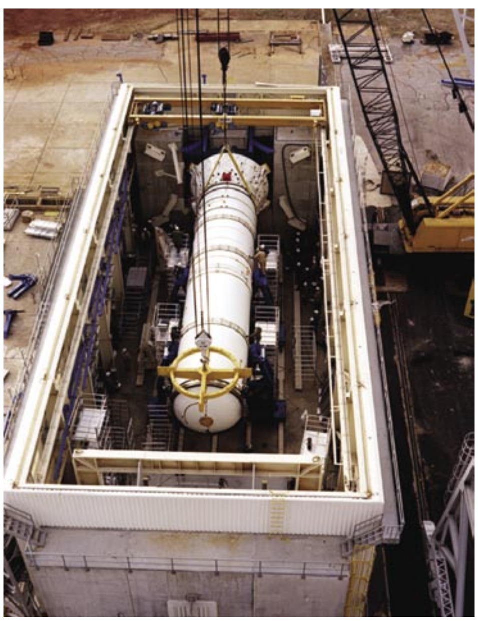
Component/System Quasi-static Load Testing

Facilities designed for smaller structural test articles are also available. Several modular reaction structures ranging from 200 ft^3 to 8,000 ft^3 exist for testing smaller test articles requiring multiple load application points. For test articles requiring uniaxial loads, a large tensile test machine capable of applying 2,000,000 lbf in tension or compression to failure (shock) loads, and 3,000,000 lbf in tension or compression without failure (no shock) is available. This machine can accommodate test articles measuring up to 10 ft × 10 ft × 25 ft. It is hydraulic servo controlled, has a stroke of 3 ft, and speed ranges up to 3 in/min. Other tensile test machines located in the high bay have capacities of 120,000 lbf, 250,000 lbf, and 2,000,000 lbf.

Solid Rocket Booster Holddown Post quasi-static load test.

Hazardous Structural Testing

Hazardous structural strength and pressurization tests are conducted in an area controlled for hazardous test operations. The load control and data acquisition and processing systems described for the Large Structure/Full-scale Quasi-static Load Facility are common to this facility and provide identical features and performance characteristics. The test bay, measuring 40 ft × 94 ft × 48 ft, has a 5-ft-thick reinforced concrete floor with 12-ft-thick end walls capable of reacting loads of 2,500,000 lbf. The roof is removable to allow for installation and removal of large structural test articles. The floor is below grade and designed for containment of pressurization fluid in the event of a hydrostatic pressurization test article rupture. An overhead bridge crane provides two independent trolleys rated at 5,000 lbs for test article handling.



Solid Rocket Motor hazardous structural testing.

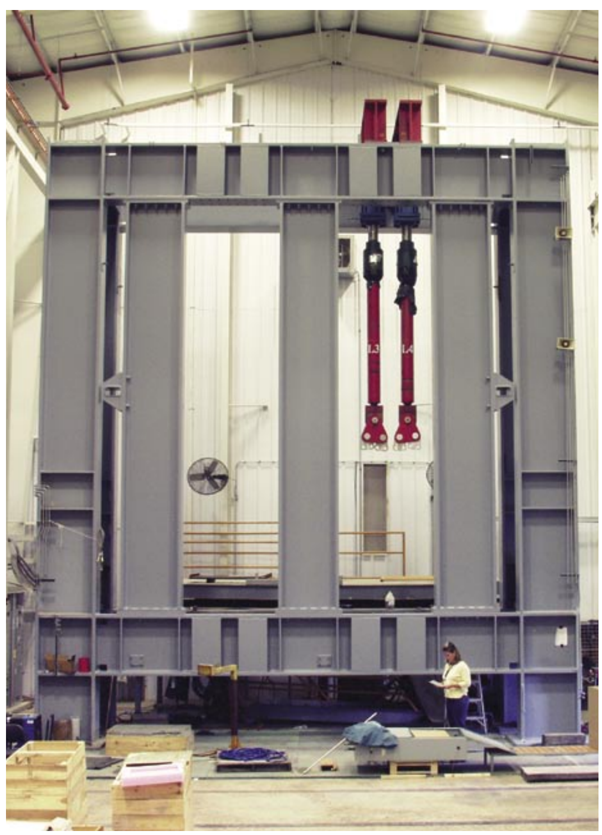
Cryogenic Structural test of Next Generation Launch Technology composite liquid hydrogen tank.

Cryogenic Structural Testing

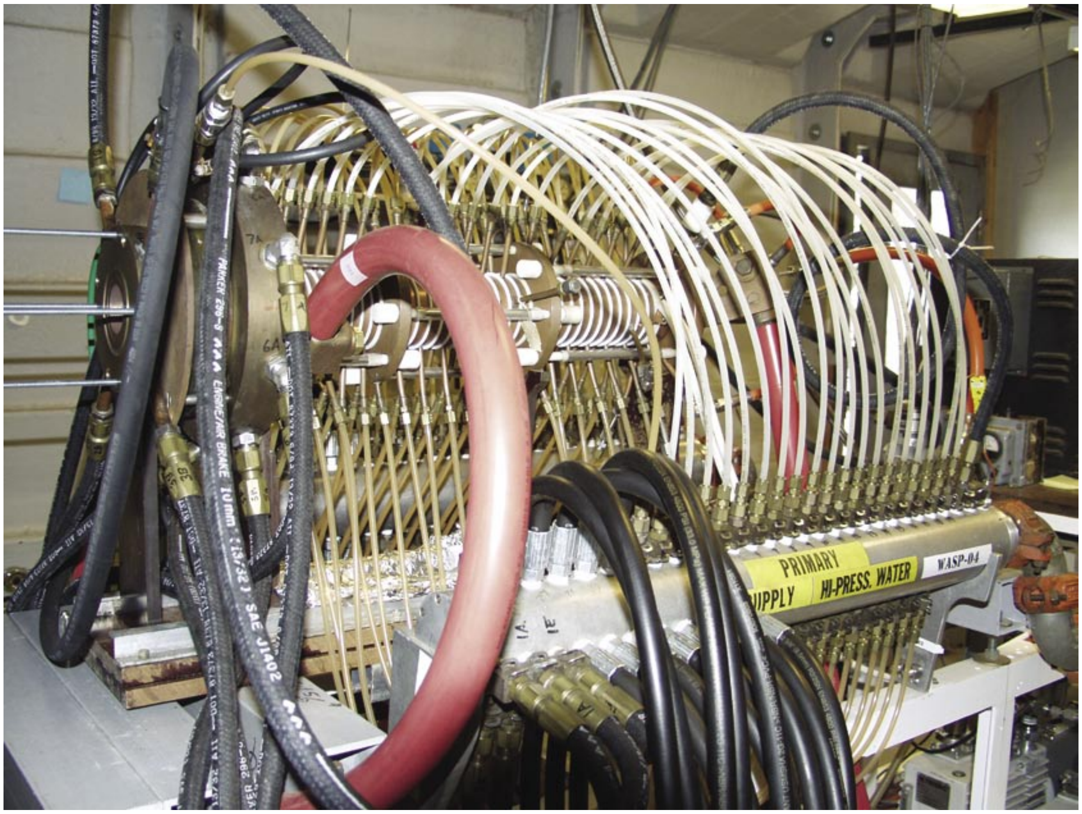
Cryogenic structural strength pressurization tests are conducted in an area controlled for hazardous test operations. Cryogenics available include liquid nitrogen, liquid helium, and liquid hydrogen which are stored in volume for large test articles. The load control, data acquisition, and processing systems described for the Large Structure Quasi-static Load Facility are common to this facility and provide identical features and performance characteristics. Test article dimensions up to 33-ft diameter and 60-ft length are accommodated. A load reaction structure is in place for tensile, compression, moment, and shear loads. Unique support structure and interface hardware are customized to test article requirements.

Combined Environments Biaxial Loads Testing

The Combined Environments Facility is able to induce tensile or compressive loads up to 1,500,000 lbs in each of two axes onto flat or curved test articles up to 10 ft square or tanks up to 10 ft in diameter and 12 ft high (dome to dome). Thermal and acoustic environments are then combined with the structural loads capability resulting in a thermal protection system test facility capable of biaxial loads, acoustics up to 172 decibels, substrate dynamic response, radiant heat up to 30 BTU/ft^2-sec, and substrate cryogenic conditions as low as –253 °C.



Combined Environments Facility.



Arc Heater.

Arc Heater

The 1.5-MW Arc Heater Facility, activated in 2004, was originally planned to test the thermal and ablative response of materials used in the Shuttle Solid Rocket Motor nozzle. This facility was later configured to perform magneto hydrodynamic propulsion studies. A project is underway to configure the arc heater capabilities to include multiple gases (air, argon, hydrogen, and carbon dioxide), vacuum environment, multiple test specimen rotation, and a water-cooled, pneumatic testing system.

Hot Gas Testing

Hot Gas Testing utilizes a gaseous hydrogen/air combustion-driven wind tunnel used primarily for thermal protection system testing and aero thermal environments definition. During a test, combustion products are expanded from the combustion chamber through a two-dimensional nozzle into a 16 in × 16 in × 40 in test section. A Mach 4 flow environment is induced and convective heating from 4.5 to 25 BTU/ft^2-sec at total temperatures from 843 °C to 1,371 °C can be obtained. The tunnel test section includes a 300-kW radiant heat system, a model insertion system with varying wedge angles, and test section shutter doors to protect the test article from start-up and shut-down shocks. The radiant heat system provides from 0 to 33 BTU/ft^2-sec and can be combined concurrently with the Mach 4 convective heat inputs for a truly unique capability. Radiant-only heating with programmable vacuum is also available. All heating environments can be individually profiled within the parameters of the facility to follow a prescribed flight heating profile. Upon request, oxygen may be added to the flow to maintain 21 percent oxygen. Test environments can also be generated to follow a test article surface or substrate temperature profile. Hot Gas Testing offers infrared thermal imaging. Video of test articles can be recorded at 30 to 10,000 frames per second.

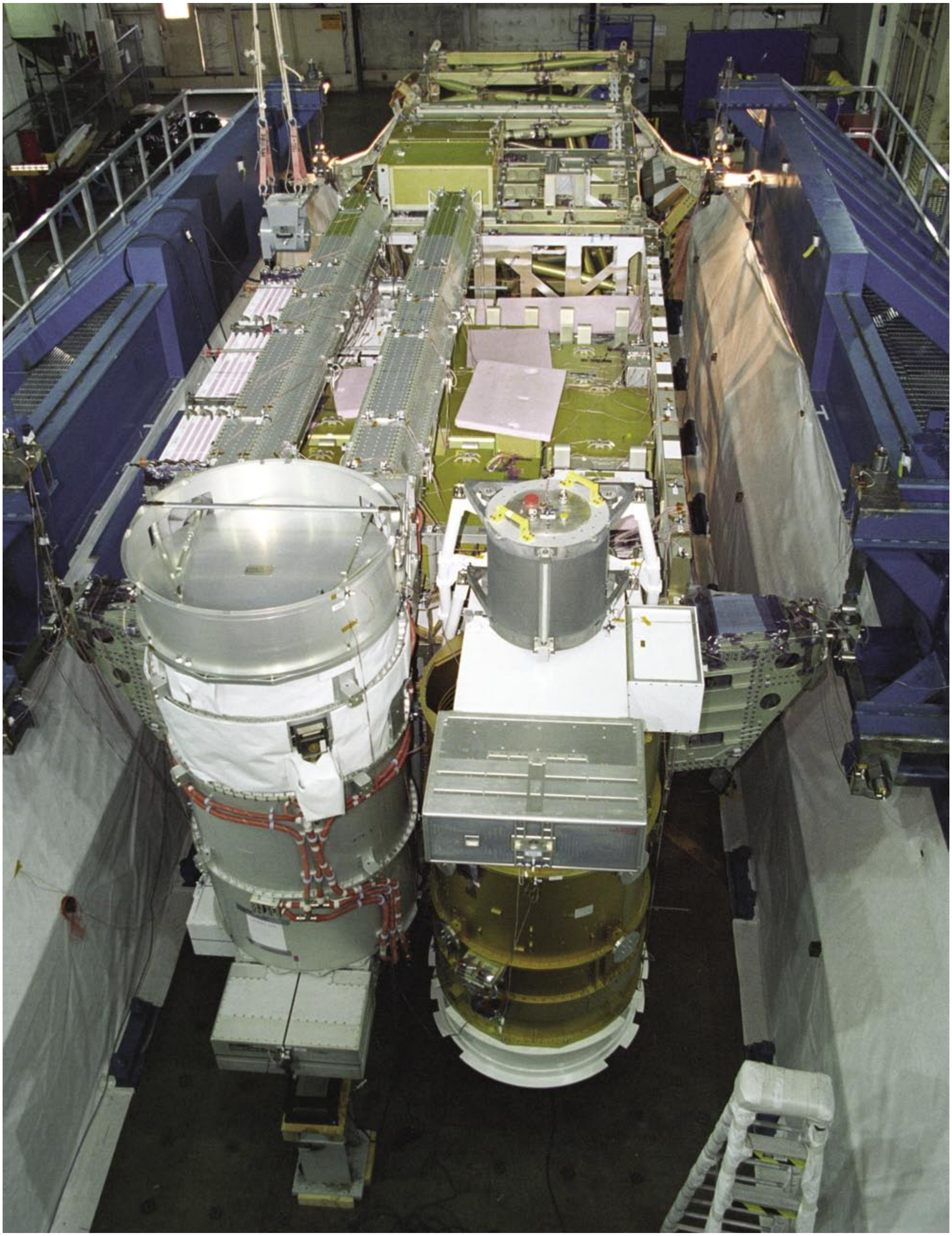
Hot Gas Testing Facility.

Hot Gas Test personnel have extensive experience with test article fabrication and instrumentation. Up to 72 channels of instrumentation can be dedicated to each test article; more channels are available upon request. Machine shop capabilities are also available on site.

External Tank Return To Flight foam testing.

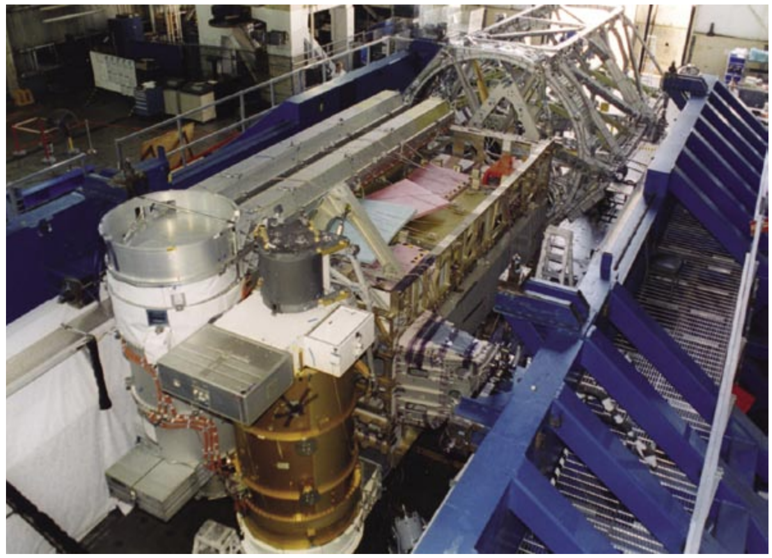
Structural Strength Test Support

A wide range of skills provide the customer with a rapid response for structural testing needs. Test engineers provide overall management and coordination of test activities. Instrumentation and load control engineers support test engineers in accomplishing all test requirements to ensure that all measurement and force loading profiles are properly addressed and performed. Mechanical technicians perform set-ups of mechanical reaction fixtures, hydraulic load application equipment, and test articles. Electrical technicians install and functionally verify (mechanically and electrically) test article instrumentation, strain gauges (including cryogenic applications), and other devices/sensors to measure displacements, loads, pressures, temperatures, etc.



ISS P6 cargo element in MSFC modal test bed.

Structural Dynamics Testing



Modal test of *ISS* P3/P4 truss elements.

Structural dynamics test technologies and facility capabilities are planned, developed, and applied to the requirements of structural analysis, flight criteria, and institutional objectives. Primary emphasis is on: certification testing to simulated flight levels; development tests to determine structural performance characteristics; experimental tests to derive structural dynamic properties, expand test technologies, and support related technology development; and experimental tests to evaluate control system technologies and concepts to mitigate structural, thermal, and control system interactions for large space structures. Test control and response data processing includes time, frequency, and spatial domain analysis formatted for compatibility with analytical models, certification criteria, and experimental objectives.

Vibration Testing

Vibration testing is conducted utilizing two separate test cells located adjacent to high-bay structures. A total of eight electrodynamic exciters and five amplifiers are dedicated to development, qualification, and certification testing of flight and ground support hardware. Dynamic excitation controlled up to 40,000 lbf is available through the use of digital vibration control systems. The control systems provide sine-sweep, broadband random, sine-on-random, random-on-random, classical shock, and shock response spectrum (SRS) control functions. Other control features include 80-dB dynamic range, 32 channels of real-time control, tolerance limited spectra, test article response limitation, and real-time signal analysis. Shaker head expanders allow mounting surfaces up to 5 ft × 5 ft. Acceleration data can be acquired in real time for up to 32 channels in both time and frequency domains and formatted to conventional and specified test article requirements. An additional 48-channel recording capability can be utilized for post processing of dynamic response data. Customized vibration fixture design and manufacture can be provided through in-house organizational resources.

Vibration test of the *ISS* Environmental Control and Life Support System Distillation Assembly.

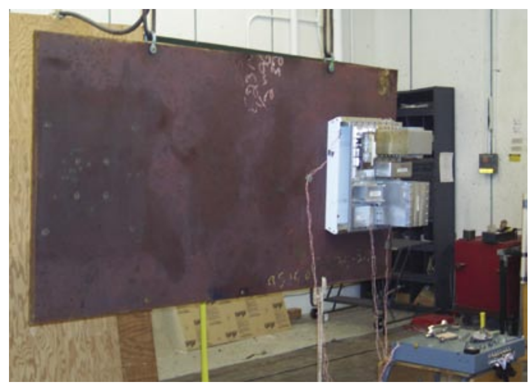
Acoustic emission measurements on the Microgravity Experiment Research Locker/Inubator (MERLIN).

Acoustic Testing

Acoustic testing is conducted utilizing a reverberation chamber, a progressive wave tube, and an anechoic chamber. Acoustic development and certification testing is performed in a 5,000-ft^3 concrete chamber with capabilities of up to 200 kW of acoustic input, 172-dB overall (OA) sound pressure level (SPL) in a progressive wave tube and 164-dB OA SPL in a diffuse field. Test articles up to 500 ft^3 can be placed in the diffuse field. Electromagnetic drivers are available for noise levels up to 139-dB OA SPL. An adjacent 3,000 ft^3 anechoic chamber provides the capability for transmissibility and absorption studies, as well as acoustic emission measurements. Up to eight microphones can be multiplexed for acoustic level control and 32 channels of acceleration response can be analyzed online. Control tolerances are ±2 dB per one third octave and ±2 dB overall from 50 to 10 kHz.

Pyrotechnic Shock Testing

Pyrotechnic shock testing is conducted in an area equipped for generating dynamic transients with explosive materials. Mild detonating fuses, linear-shaped charges, and blasting caps are used to generate flight input transient shock simulation to test hardware commonly mounted on a suspended steel plate. Shock levels up to 50,000 Gs SRS and 10 kHz can be generated. Pyrotechnic devices used in aerospace flight applications can be evaluated and characterized in relation to the SRS resulting from detonation. Twenty channels of transient pyrotechnic response data can be acquired and post processed in the time domain or SRS for one pyrotechnic event.

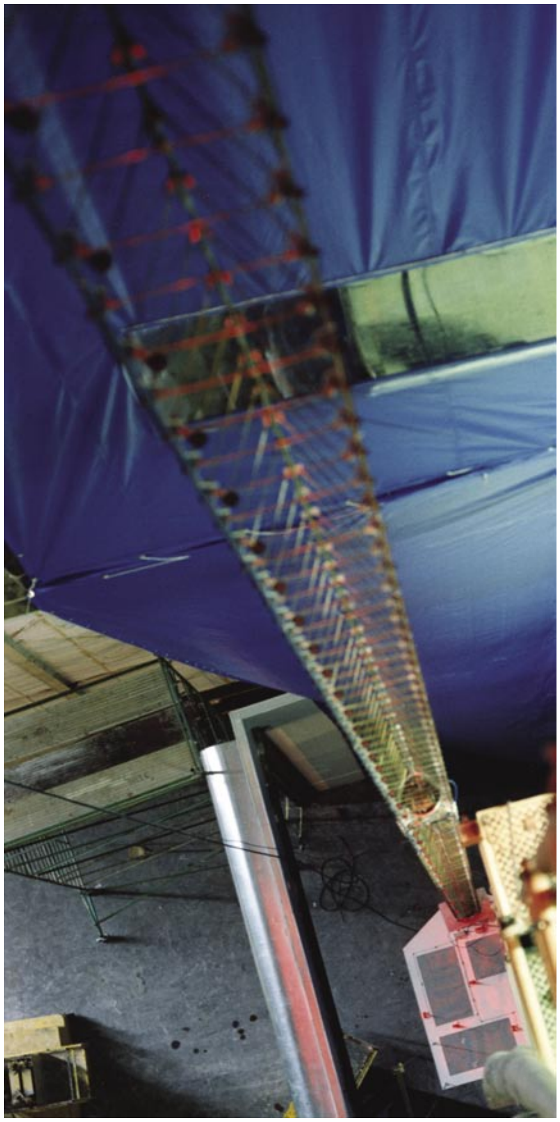


Pyrotechnic shock test of Propulsive Small Expendable Deployer System (ProSEDS).

Modal Testing

The Space Shuttle's Orbiter Boom Sensor System Modal Testing.

The MSFC Modal Test Facility is equipped to conduct modal and other related dynamic testing on a variety of hardware, including flight systems, payloads, and components. Testing may be conducted in the MSFC test facility or at a customer facility. Fixed, free-free, or hybrid boundary conditions may be accommodated. Customized fixtures may be designed and manufactured through MSFC organizational resources. The modal test facilities include two high bays with crane access, as well as a 30 ft × 30 ft × 30 ft enclosure which can be conditioned into an ISO Class 8 clean room environment. Excitation may be provided by a variety of impulse hammers or electromagnetic shakers using transient, sinusoidal, or random inputs. A broad range of shakers are available from small 2-lb shakers to 1,000-lb shakers. Over 1,200 standard integrated circuit piezoelectric accelerometers are available for instrumentation of the test article. In addition, other types of accelerometers are available depending on the test requirements. The accelerometer inventory includes approximately 50 channels of very sensitive direct current accelerometers which can measure both very low response levels and very low frequency. Dynamic measurements are accomplished through an inventory of dynamic signal analyzers ranging from 2 channels to 260 channels of simultaneous data acquisition. Some of the analyzers use integrated software while others are controlled by software running on computer workstations. For large test articles, conventional multi-input, multi-output testing is conducted primarily using simultaneous burst-random excitation. Modal analysis of the frequency response functions generated during data acquisition is performed using a variety of advanced parameter estimation techniques which result in the modal parameters of the test article—frequency, damping, and mode shapes. Test data and modal analysis results may be provided in a number of electronic formats to facilitate model correlation by the customer. In recent years, a number of more nonconventional modal testing capabilities have been developed and used to acquire dynamic data, particularly in the area of noncontacting and full-field measurements. These capabilities include laser vibrometry, electronic speckle pattern interferometry, and photogrammetry.



Large deployable structural system.

Control Dynamics

There are three test-beds that address the control of large flexible structures with dynamic and thermal interactions and dynamic isolation system applications. Capability is provided to implement, test, and verify system indentification concepts and control system algorithms for lightly damped, highly coupled systems. The main structural elements for these facilities are deployable booms, 45 ft and 100 ft in length, suspended vertically and outfitted with a complement of instrumentation including accelerometers, rate gyros, and position sensing systems. The booms are structurally characterized by light damping (≤1 percent), low-fundamental frequencies (≤0.25 Hz), and high-densities modal. Various rotational and translational control actuators are available ranging from proof-mass actuators to precision-gimbaled pointing mounts. External disturbance force profiles can be imparted to the facilities through a two-axis hydraulic table and a two-axis, air bearing-supported, electrodynamic exciter.

Space Shuttle Main Engine flowliner modal testing by MSFC Test engineers at Kennedy Space Center.

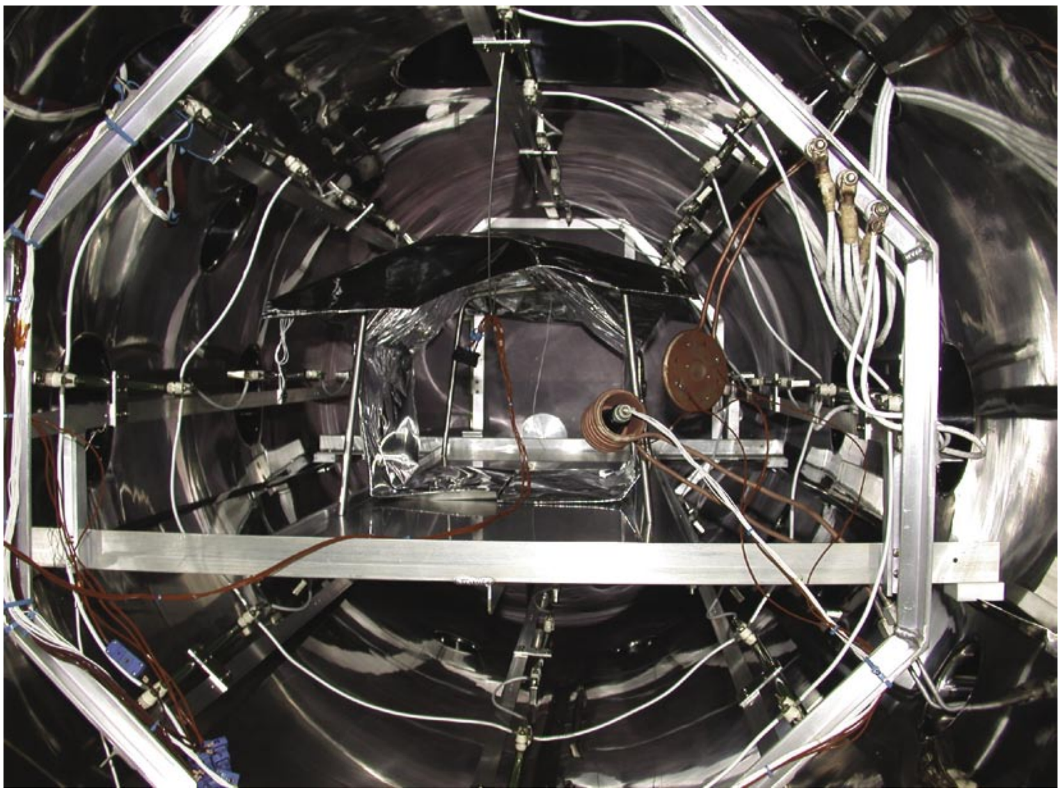
Structural Dynamics Test Support

A wide range of skills provide the customer with a rapid response for structural dynamics testing needs. Test engineers provide overall management and coordination of test activities. These engineering services span a wide variety of dynamics testing: modal survey, vibration, acoustics, control dynamics, and pyrotechnic shock. Force inputs are provided through electromagnetic shakers, instrumented hammers, pyrotechnic charge devices, and forced air horn loaded drivers. Measured responses are obtained through piezoelectric accelerometers, high-speed video, dynamic strain gauges, electronic speckle pattern interferometry, and noncontact laser vibrometry. Test data are provided to support correlation of the experimental results with the analytical structural models and to qualify and certify flight hardware.

The ETF's largest chamber (V-20) is 20 ft in diameter and 28 ft long. With a 6-DoF Stewart platform inside the chamber, it is capable of providing automated rendezvous and capture in the simulated space environment.

Environmental Testing

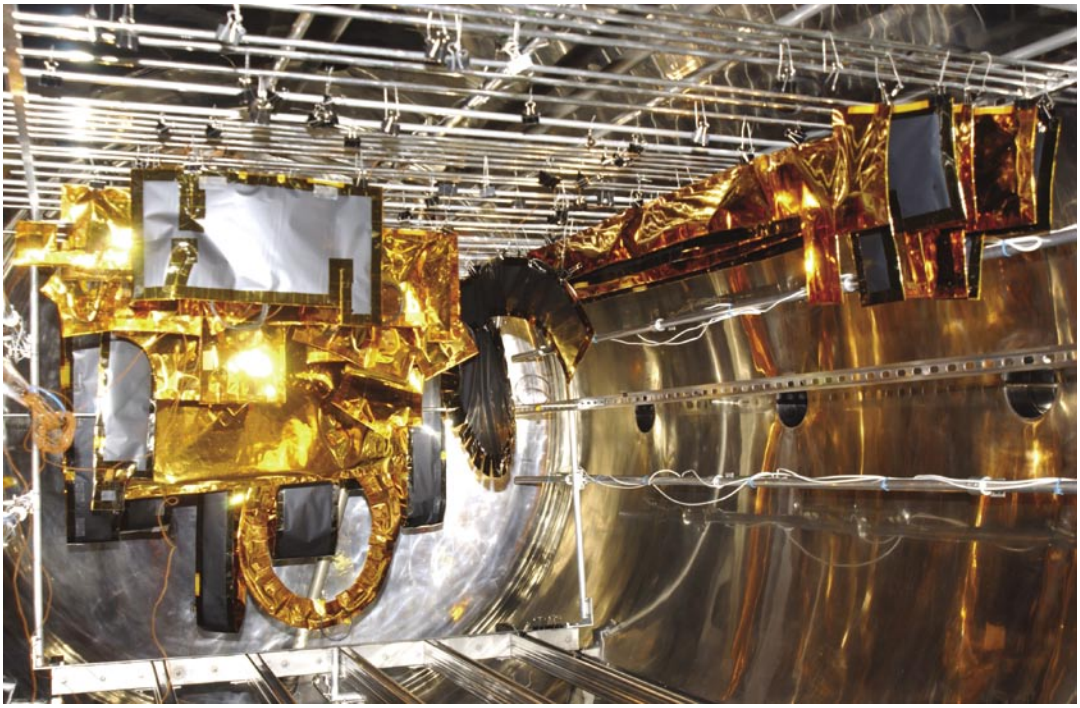
Environmental testing simulates the extreme environments that space hardware is expected to withstand during flight. The Environmental Test Facility (ETF) provides these environments using vacuum chambers capable of high vacuums, simulated launch pad storage or high altitude conditions. Space temperature simulation is accomplished using liquid nitrogen shrouds and cold plates for cold conditions and infrared lamps for the solar radiation heating. Feed throughs in chamber walls provide electrical, mechanical, and fluid connections to the test article. The ETF consists of 27 chambers to address these extreme environmental conditions.



Optical Cleanliness Bakeout Chambers are equipped with a temperature-controlled quartz crystal microbalance, and an optical witness sample to measure adsorption and desorption of volatile condensable materials.

Optical Cleanliness Thermal Vacuum Bakeout

MSFC Specification 1238 is one of the most stringent certifications of optical cleanliness. The ETF has had great success in certifying hardware to this standard and is recognized as a leader in optical cleanliness vacuum bakeout. The ETF has been used to certify the



Multilayer Insulation Blankets are suspended in a vacuum chamber just prior to a vacuum bakeout, which is performed to remove contaminants from the blankets to prepare them for installation on a spacecraft.

cleanliness of components used on the Chandra X-ray Telescope and the Hubble Space Telescope. Future optical cleanliness vacuum bakeouts include the Solar-B Telescope and James Webb Space Telescope. There are three ETF test chambers used for MSFC Specification 1238 bakeouts. The entry doors of two chambers are inside an ISO Class 7 clean room and the entries of the third chamber is in an ISO Class 8 clean room. Instrumentation includes thermocouples, resistive thermal devices, ionization and convectron pressure transducers, temperature-controlled quartz crystal microbalances, optical witness sample mirrors, and residual gas analyzers.

Vacuum Bakeout

Thermal vacuum bakeouts are performed in six chambers. Vacuum bakeout cleans components before flights and prior to testing for certification to optical cleanliness specifications. Instrumentation includes thermocouples and convectron and ionization pressure gauges.

Thermal Vacuum Testing

The ETF performs approximately 200 tests per year with most being thermal vacuum tests. The ETF is equipped to perform thermal vacuum tests in any of 12 different chambers. These chambers range in size from 20 ft × 28 ft to 2 ft × 2.5 ft. The largest of the ETF chambers is certified to accept test articles weighing up to 15 tons; additionally, it has available a six-degrees-of-freedom (6-DOF)

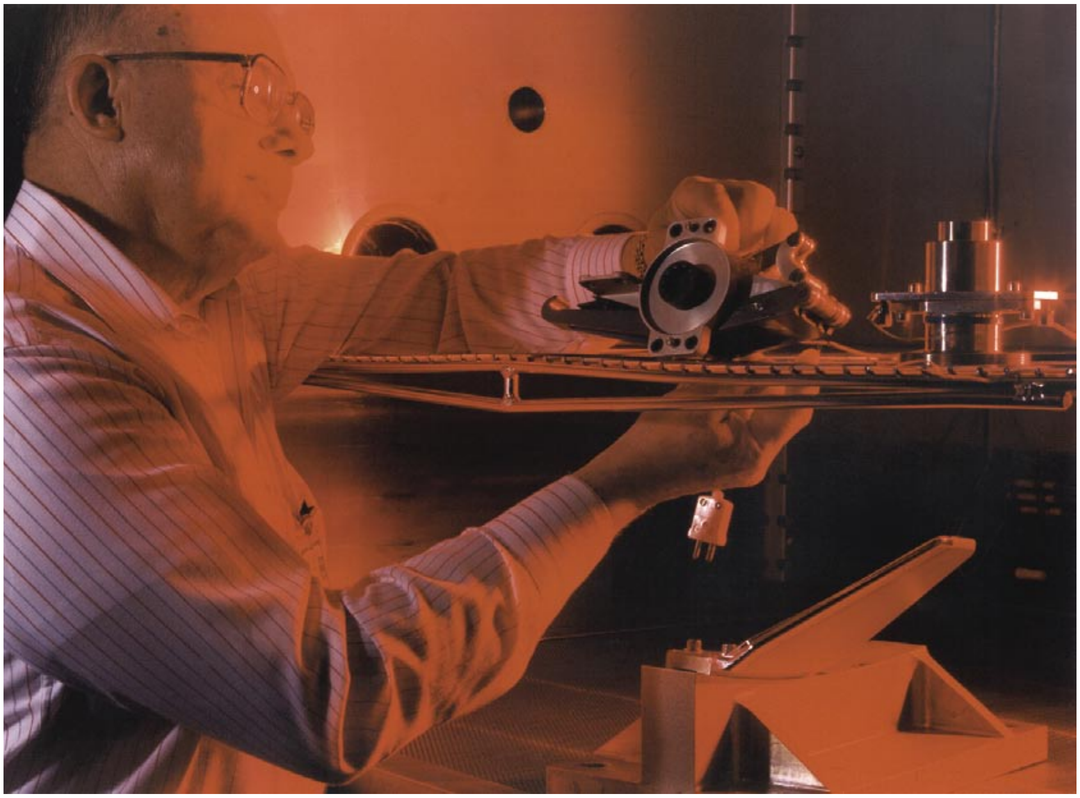
Technicians use an overhead crane to open the top of a vacuum chamber and remove a test article. All technicians in the ETF are certified to handle program critical hardware.

Astronaut Dominic A. Antonelli practices Reinforced Carbon-Carbon (RCC) Crack Repair techniques with the RCC and repair materials in simulated on-orbit conditions. Being able to practice the skills in a ground test facility prior to an extravehicular activity increases the likelihood of success on-orbit.

Stewart platform for positioning in the chamber. With the 6-DOF mechanism, test articles can be remotely docked or berthed in the simulated environment of space. The system was developed to test the *ISS* common berthing mechanism and can position devices weighing hundreds of pounds. It is the only facility of its kind in the country. Instrumentation available for thermal vacuum facilities includes thermocouples, resistive temperature elements, ionization and convectron pressure gauges, temperature-controlled quartz crystal microbalances, and a residual gas analyzer.

Life Cycle Testing

The performance of hardware in space over decades can be simulated in a long-term thermal vacuum test. Two of the thermal vacuum chambers are used for life cycle testing of space hardware. One chamber is equipped with vacuum-rated motors that can position a test article in a liquid nitrogen shroud for rapid cooling. The chamber then has the capability to reposition the article near an array of infrared lamps for rapid heating. When equipped with a spacesuit arm and glove and viewport (as shown above), the chamber can be used for pilot-in-the-loop simulation. Currently it is being used to research on-orbit crack repair of reinforced carbon-carbon, the material on the leading edge of the Shuttle's wing. Pilot-in-the-loop simulations can be used to test the effects of the space environment on many Extravehicular Activities that astronauts perform. The other chamber last performed a continuous 18-year life-cycle test of an electrical contact slip ring. The test was started April 1984 and ended in October 2002 with the chamber continuously maintaining the required high-vacuum environment.



An engineer instruments a test article prior to exposing it to thermal humidity testing to simulate the on-orbit environment it will be exposed to inside the *ISS*.

The rapid decrease in pressure a Shuttle External Tank (ET) experiences as the tank is launched is simulated in a test chamber. ET foam panels are exposed to the cold temperature (~–240 °C) of the liquid propellants on one-side (inside), and the heat of friction (~343 °C) as it passes through the atmosphere on the other side (outside).

Launch Simulation Testing

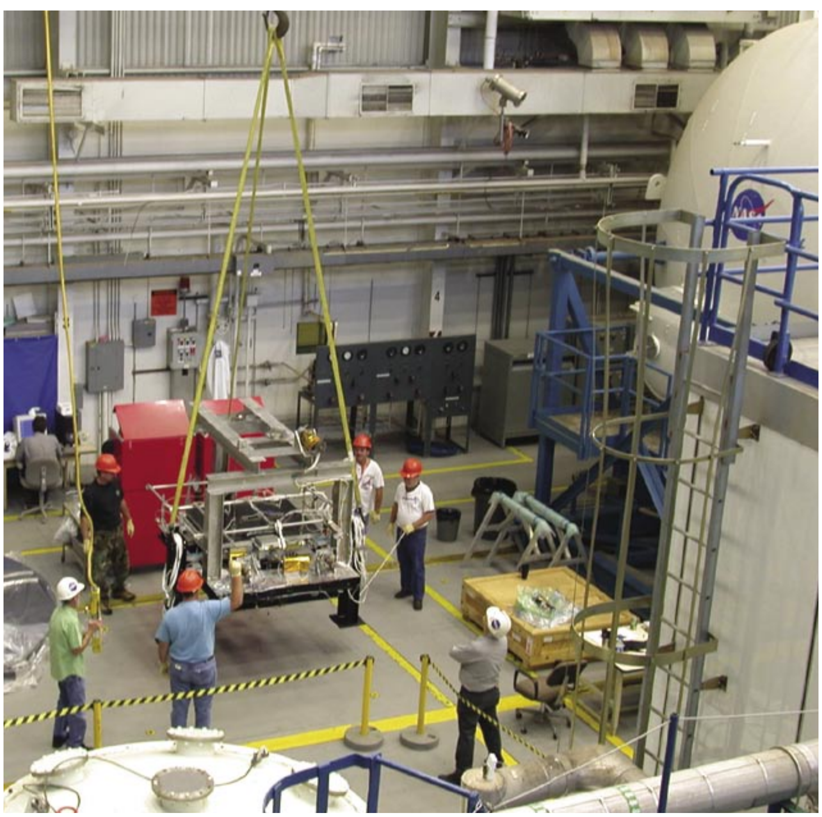
During launch, any flight hardware exposed to the external environment will undergo a rapid pressure change from one atmosphere to a high vacuum within minutes. Likewise, there is a rapid pressure increase upon reentry into the Earth's atmosphere. This facility has the capability to accurately simulate the rapid dynamic depressurization and repressurization experienced during launch and reentry. In addition, two chambers are equipped with cryogenic systems and banks of high-energy infrared lamps that can provide temperature extremes of –240 °C to +343 °C during launch simulation testing. Instrumentation includes thermocouples, proportional valve position indication, convectron and ionization pressure gauges, and high-speed video cameras.

Thermal-Humidity-Altitude Testing

Environmental simulations of extreme temperatures, humidity, and high-altitude pressures can be achieved in one of the thermal-humidity-altitude test chambers. Thermal conditions alone or thermal conditions and controlled humidity can be simulated in the thermal humidity test chambers. Atmospheric flight conditions with extreme temperature, low pressures, and controlled humidity are simulated in the thermal altitude chambers. The thermal humidity and thermal altitude chambers are cost-efficient tools for research of the thermal stability of materials since operational cost is about a third of the operational cost of a comparably sized vacuum chamber. Instrumentation includes thermocouples, humidity sensors, and pressure gauges.

Environmental Test Support

A wide range of skills provide the customer with a rapid response for environmental testing needs. Test engineers provide overall management and coordination of test activities. These engineering services span a wide variety of environmental testing: thermal vacuum, thermal altitude, thermal humidity, launch pressure simulation, and vacuum bake out. Technician support for environmental testing include skills in leak detection, welding, electrical systems, mechanical systems, and machine fixture fabrication. Additional capabilities include customized cold plate design and fabrication and special chamber feedthroughs to support vacuum operations.

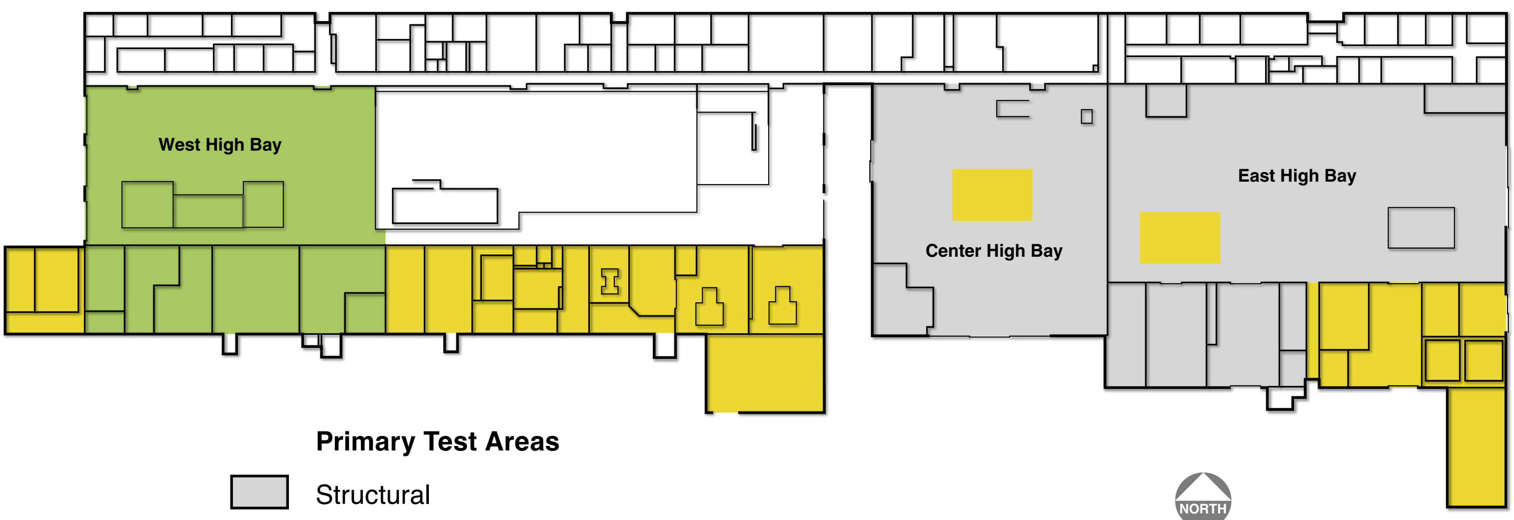


Technicians lift a test article destined for the *ISS* and its test fixture into a thermal vacuum chamber.

Technicians install a test article in its test fixture and instrument it with thermocouples in preparation for a thermal vacuum test to verify the test article's ability to function in space.

Environmental Test Facility Chamber Capabilities Matrix					
Chamber	Primary Use	Vaccuum Pressures	Temperatures	Thermal Conditioning	Dimensions
V1	Optical Cleanliness	5×10^{-7} torr	Ambient to 180 °C	IR Lamps	4 ft dia × 7 ft
V2	Optical Cleanliness	5×10^{-7} torr	Ambient to 180 °C	IR Lamps	4 ft dia × 10 ft
V3	Pilot-in-the-Loop On-Orbit Simulation	5×10^{-8} torr	–100 to 100 °C	IR Lamps, LN_2	4 ft dia × 10 ft
V4 & V-8	Vacuum Bakeout	1×10^{-6} torr	Ambient to 175 °C	IR Lamps	2 ft dia × 2.5 ft
V5	Thermal Vacuum	1×10^{-6} torr	–170 to 150 °C	IR Lamps, LN_2	3 ft dia × 4 ft
V6	Thermal Vacuum	1×10^{-7} torr	–170 to 150 °C	IR Lamps, LN_2	3 ft dia × 4 ft
V7	Vacuum Bakeout	5×10^{-7} torr	–170 to 150 °C	IR Lamps, LN_2	8 ft dia × 10 ft
V9	Vacuum Bakeout	1×10^{-6} torr	Ambient to 170 °C	IR Lamps, LN_2	4 ft dia × 7 ft
V10	Life Cycle	5×10^{-8} torr	Ambient	N/A	1.5 ft dia × 1.5 ft
V11/RAC	Launch Simulation	1×10^{-6} torr	–240 to 340 °C	IR Lamps, LHe	4 ft dia × 10 ft
V12	Vacuum Effect Demo	1×10^{-6} torr	–100 to 100 °C	IR Lamps, LN_2	1.5 dia ft × 2 ft
Rome	Thermal Vacuum	1×10^{-7} torr	–170 to 180 °C	IR Lamps, LN_2	12 ft dia × 20 ft
Sunspot	Thermal Vacuum	1×10^{-6} torr	–170 to 200 °C	IR Lamps, LN_2	10 ft dia × 12 ft
V20	Thermal Vacuum	1×10^{-6} torr	–170 to 200 °C	IR Lamps, LN_2	20 ft dia × 28 ft
TH1–TH3 and TH5–TH8	Thermal Humidity	Ambient	–70 to 190 °C	Electrical resistive and refrigeration	4 × 4 × 4 ft
TH4	Thermal Humidity	Ambient	–70 to 160 °C	Electrical resistive and refrigeration	4 × 5 × 4 ft
V14/MEG	Vacuum Bakeout	1×10^{-6} torr	Ambient to 150 ºC	IR Lamps	12 × 8 ft
TA1	Thermal Altitude	Ambient to 100,000 ft	–70 to 190 °C	Electrical resistive and refrigeration	4 × 4 × 4 ft
TA2	Thermal Altitude	Ambient to 150,000 ft	Ambient to 200 °C	Electrical Resistive	1.5 × 2 × 1.5 ft
TA3	Thermal Altitude	Ambient to 200,000 ft	Ambient to 200 °C	Electrical Resistive	1 × 1.5 × 1 ft

Structural and Environmental Test High-bay Facility.



Primary Test Areas

- Structural
- Dynamic
- Environmental

Facilities Overview

Building 4619 is a high-bay facility complex that provides laboratory space, test cells, and utility support for structural and environmental test activities. Three high-bay structures are provided: the center high bay, the east high bay, and the west high bay. Utilities provided included gaseous nitrogen at pressures up to 5,000 psig, liquid nitrogen, high-purity air at pressures up to 3,500 psig, shop air at pressures up to 100 psig, and 60Hz electrical power up to 480 VAC (3 phase). A backup generator and uninterruptible power supplies ensure that data acquisition will be continuous in the event of a power outage.

The center high bay features a movable crosshead, mounted on four towers, which can be bolted off in any 5½-in increment between 40 ft and 115 ft. The 81 ft × 82 ft high-force floor under the crosshead contains 2,356 floor tie downs on 18-in centers designed to accept 2¾-in diameter bolts or studs. Each tie down is capable of reacting 111,300 lbf vertically and 19,700 lbf laterally. Massive walk platforms spanning the two north towers at intervals of 20 ft are designed to react shear loads. The facility is capable of reacting 30,000,000 lbf vertically and 2,400,000 lbf laterally and can accommodate test articles up to 100 ft high and 54 ft in diameter. Two bridge cranes, each with two independent 15-ton trolleys, are attached to the crosshead and are used to install test fixtures and test articles.

The east high bay has a high-force floor measuring 154 ft × 64 ft and can accommodate test articles up to 75 ft in height. Floor tie down pads are provided on 10-ft centers. Each tie down pad is capable of reacting 340,000 lbf vertically and 44,000 lbf laterally and contains 4 tie downs on 18-in centers designed to accept 2-in diameter bolts or studs. Two bridge cranes, each with a single trolley having 20-ton and 5-ton winches provide ground support capability.

The west high bay houses the ETF chambers. The ETF chambers can accommodate major component test articles of sizes up to 18 ft × 26 ft and weighing up to 15 tons. Small test articles can be tested in one of the three bell jar chambers. Machine fabrication capabilities are housed on the south side of the west high bay. This facility provides a small fixture manufacturing capability for quick turnaround testing. Two bridge cranes over the high bay providing a combined lift capacity of 20 tons are available for handling large test articles. Two clean rooms, ISO class 7 and class 8, are utilized for contamination-sensitive equipment.

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